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(54) Fuel cell protection circuits

(57) A fuel cell protection circuit comprises an overvoltage sensor 46 monitoring the fuel cell output voltage; a protective load 44; and a load connecting means 42 responsive to an overvoltage signal for connecting the protective load 44 to the fuel cell 22 when the fuel cell output voltage reaches a predetermined level to limit an overvoltage excursion of the fuel cell by providing a current path for the fuel cell output.

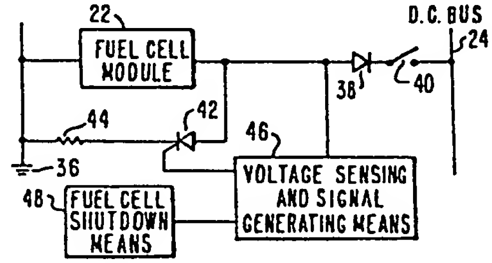

FIG. 3

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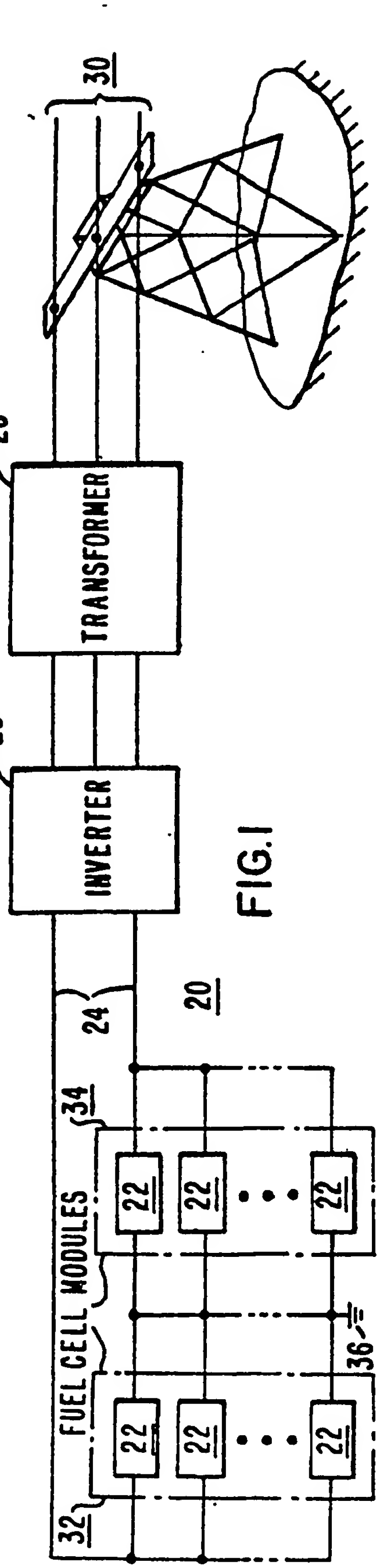

FIG.1

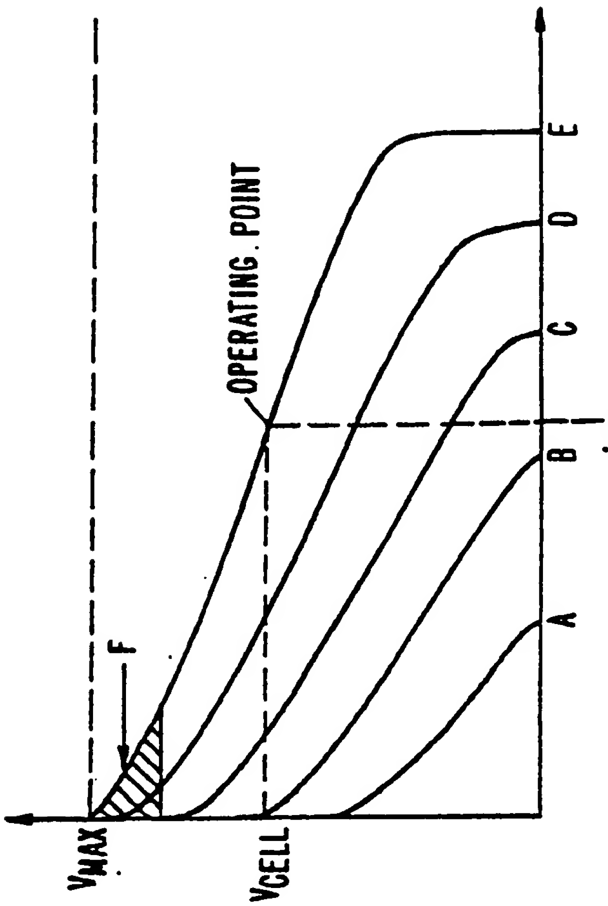

FIG. 2

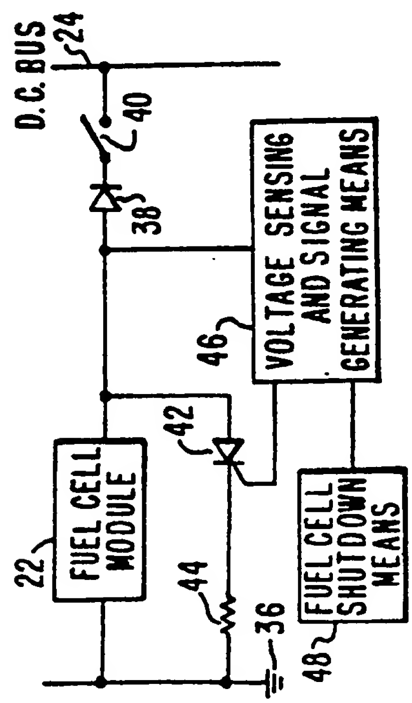

FIG. 3

SPECIFICATION

Improvements in or relating to fuel cell protection circuits

This invention relates to fuel cell protection circuits for the control of a group of fuel cells electrically connected in parallel, and specifically for protecting the fuel cell during periods of start-up, shut-down and transient operation.

Individual fuel cells can provide direct current (DC) power with voltage and current characteristics that may vary depending on a wide variety of factors such as fuel (pressure, quantity and type), oxidant (pressure and quantity), fuel cell age, fuel cell temperature and other factors. When multiple fuel cells are connected in parallel to a DC bus, an individual fuel cell can be damaged if it undergoes extreme voltage transients. The connecting devices will have to be rated to interrupt worst case steady state short circuit currents. Under fault conditions very high currents could be approached for a few milliseconds. What is needed is a means to protect the individual fuel cell from damage during such a transient.

Further, it may become necessary to service the fuel cell without disruption of DC bus power. What is needed is a means to remove from and return to service an individual fuel cell without affecting the DC bus. DC current and voltage waves do not have natural zero points as AC waves do and this complicates their interruption. When a DC switch contact opens, the arc which forms can be extinguished and the flow of current interrupted in three ways: (1) by lengthening and cooling the arc, (2) by counterpulsing (injecting a pulse of current of opposing polarity through the contact) to create a momentary zero condition or (3) by interrupting the current flow at another point in the circuit.

Mechanical disconnect switches, either manually or motor operated, are readily available to perform the required closing and power handling functions, but they are slow and may not be rated for the particular DC load interrupting requirements.

AC circuit breakers are sometimes used for DC service. When this is done, special tests are performed to determine what the DC handling capabilities are in the particular application. Some data is available for small circuit breakers, but none has been found at certain higher ratings.

Single pole DC circuit breakers capable of handling 4000 amperes at 3000 volts DC are manufactured by AEG Telefunken in Europe, but their current ratings are higher than may be necessary and their voltage ratings are lower. Special tripping and control circuits would be required in order to use them; so they are not an ideal solution.

According to the present invention a fuel cell protection circuit comprises a voltage sensing and signal generating means for sensing the fuel cell output voltage and generating a signal with respect thereto; a protective load; and a load connecting means responsive to said signal for connecting said protective load to said fuel cell when said fuel cell output voltage reaches a predetermined level to limit an overvoltage excursion of said fuel cell by providing a current path for the fuel cell output.

The invention also includes a fuel cell system protection circuit which comprises a voltage sensing and signal generating means for sensing the fuel cell output voltage and generating a signal with respect thereto; a protective load; and a load connecting means responsive to said signal for connecting said protective load to said fuel cell when said fuel cell output voltage reaches a predetermined level to limit an overvoltage excursion of said fuel cell by providing a current path for the fuel cell output.

In order that the invention can be more clearly understood, a convenient embodiment thereof will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a block diagram of a conventional fuel cell power generation station,

Figure 2 is a voltage vs. current characteristics curve of a conventional fuel cell, and

Figure 3 is a schematic diagram of a fuel cell system.

Referring now to Fig. 1, there can be seen a schematic of a typical fuel cell power station 20, showing fuel cell modules 22 electrically connected in parallel to a DC bus 24. The DC bus 24 in turn is connected to a DC to AC converter, which may be an inverter 26, as is well known in the art. The inverter 26 in turn is connected to transformers 28 which may supply an AC grid 30 with three phase, high voltage electrical power.

An individual fuel cell module 22 may typically have output capabilities of 350 amperes at 1100 volts DC. As shown in Fig. 1, there are two sets 32, 34 of ten fuel cell modules 22 with one side connected to a common ground 36 for each set 32, 34. This provides a DC voltage to the inverter 26 of 2200 volts, with a current capacity of 3500 amps.

Referring now to Fig. 2, there is shown a typical voltage (E) vs. current (I) graph for a typical fuel cell. Each of the curves A, B, C, D and E represent a locus of current and voltage relationships for a particular combination of fuel and oxidant supply characteristics. The specific shape of each of the curves may vary as fuel and oxidant is provided to the fuel cell at different pressure, temperatures and amounts, but in general, the locus moves upward and to the right from the zero point.

Items of particular interest are:

- No load voltages are high—typically 60—70 percent more than normal operating voltage.
- Output current reaches a limit—typically 70—80 percent more than normal operating current.
- As gas (air and fuel) flows are reduced and the amount of them left in a cell decreases, voltage and current will decrease.

- Decreasing the ratio of fuel to air has the same effect as decreasing both proportionately.
- As cell temperature and pressure are decreased, cell output will decrease.

Fig. 2 shows an operating area F in which the fuel cell will be lightly loaded and its output voltage will be relatively high. Sustained operation in such a condition will have a damaging effect on the fuel cell and should be avoided.

Under transient conditions, such as short circuiting of the output, very high currents (15 to 20 times full load) can be expected for a few milliseconds.

Looking now to Fig. 3, there can be seen a fuel cell module 22 connected between one DC bus 24 and ground 36. Also shown is a blocking diode 38 and a disconnect switch 40, connected in series with the fuel cell module 22 to the DC bus 24, and a thyristor 42 and resistive load 44 series connected, in parallel with the fuel cell module 22. The thyristor 42 is controlled by a voltage sensing and signal generating means 46 as is well known in the art. This voltage sensing and signal generating means 46 may also provide a signal to a fuel cell shutdown means 48, which may interrupt fuel or oxidant supply, or both, to the fuel cell module 22.

Based on fuel cell module 22 characteristics of 350 amps at 1100 VDC, the components shown in Figure 3 could typically have ratings as follows:

1) diode 38: 700 amps at 2000 VDC;
2) thyristor 42: 70 amps at 2000 VDC;
3) disconnect switch 40: 350 amps continuous carry, 2000 VDC standoff;
4) resistive load 44: 16 ohms, or about 1.0 kilowatt load, based on a cell shutdown time of 10 minutes from fuel cutoff.

The operation is as follows. In the event the fuel cell module 22 voltage is lower than the DC bus 24 to ground 36 voltage, the blocking diode 38 prevents the fuel cell module's 22 exposure to reverse current flow. Since there is no current flow, the disconnect switch 40 may be opened or closed without arcing. This allows the individual fuel cell module 22 to be placed into or taken out of service without disruption of the DC bus 24. This low voltage condition may be achieved intentionally by reducing flow of fuel and/or oxidant to the fuel cell module 22, or unintentionally, in the case of a fault within the fuel cell module 22 itself which might cause a low voltage condition.

In the event fuel cell module 22 voltage were to increse above acceptable levels, for example in the event of a loss of load, the fuel cell module 22 output voltage will attempt to rise to its open circuit value for the particular locus (see Fig. 2). This would be a low current, high voltage condition and could be prevented only by cutting off the fuel and oxidant gases to the fuel cell module 22 and the fuel already in the fuel cell module 22 being used up or otherwise removed instantanteously. As an alternative, a high speed electrónic switch such as thyristor 42 can be used to connect a resistive load 44 across the module and provide sufficient loading to keep the voltage down to an acceptable level until all fuel is out of the fuel cell module 22. In Fig. 3, this voltage is sensed by the voltage sensing and signal generating means 46, which will gate the thyristor 42 to an "on" state. This will allow the fuel cell module 22 to generate current, and move back down the locus (see Fig. 2) to a safe operating point. Simultaneously, the fuel cell shut-down means 48, which could be solenoid operated valves, signalled by the voltage sensing and signal generating means 46, will stop flow of fuel and oxidant to the fuel cell module 22, shutting down the fuel cell module 22.

Claims

1. A fuel cell protection circuit which comprises a voltage sensing and signal generating means for sensing the fuel cell output voltage and generating a signal with respect thereto; a protective load; and a load connecting means responsive to said signal for connecting said protective load to said fuel cell when said fuel cell output voltage reaches a predetermined level to limit an overvoltage excursion of said fuel cell by providing a current path for the fuel cell output.

2. A circuit according to claim 1, wherein the load connection means comprises a thyristor fired by the signal.

3. A circuit according to claim 1 or 2, wherein said circuit further comprises a fuel cell shut-down means for shutting down the operation of the fuel cell when said fuel cell output voltage reaches a predetermined level.

4. A fuel cell system which comprises a fuel cell; a voltage sensing and signal generating means for sensing the output voltage of said fuel cell and generating a signal with respect thereto; a protective load; a load connecting means responsive to said signal for connecting said protective load to said fuel cell when said output voltage reaches a predetermined level to limit an overvoltage excursion of said fuel cell by providing a current path for the fuel cell output; a fuel cell shut-down means responsive to said signal for shutting down the operation of the fuel cell when said output voltage reaches a predetermined level; a bus coupled to the output of said fuel cell; and a reverse current flow prevention means for preventing reverse current through said fuel cell when the voltage of said bus exceeds the output voltage of said fuel cell.

5. A system according to claim 4 wherein the load connecting means is a thyristor fired by the signal.

6. The system according to claim 4 or 5, wherein the reverse current flow prevention means is a diode.

7. Fuel cell systems as claimed in claim 4 and substantially as described herein with particular reference to Fig. 3 of the accompanying drawings.

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